

Low-Energy Initiator (LEI) Controls

Introduction

This supplement outlines the minimum safety criteria to be used by LLNL personnel in all phases of Low-Energy Initiator (LEI) operations.

LEIs are electroexplosive devices (EEDs) containing energetic materials which are designed to be initiated by an energy of 0.1 J or less. (An LEI requires less energy than an exploding bridgewire (EBW) or a slapper detonator.)

Policy

Avoid the use of LEIs when a high-energy device can be used for a specific application. It is LLNL policy to use Type-C EEDs in weapons systems and in other applications when possible. If for some significant reason an EBW or slapper device cannot be used, every effort shall be made to purchase or develop an LEI which meets or exceeds the safety criteria detailed in this Supplement.

Responsibilities

Program

The experimenter has the responsibility to obtain appropriate safety information on the EED to be used in the experiment; this information shall be submitted through the proper channels and tabulated on an Electroexplosive Component Data Sheet (Appendix A). This data enables the LEI Committee to assign the device to an appropriate LLNL Explosive Type. The information will also assist in developing safety controls necessary for the Operational Safety Procedure. If the information is incomplete, extra safety precautions will be necessary. The experimenter must incorporate these minimum design features and controls into the experiment.

LEI Handlers and Users

The Handlers and users must follow all the specified safety procedures. Each Operational Safety Procedure (OSP) authorizing the use of an LEI will specify the person responsible for the operation, and an alternate.

LEI Committee

The LEI Committee is responsible for reviewing safety controls, handling, and characterization procedures for LEIs. Specific committee responsibilities and tasks are detailed below.

Definitions

The various types of EEDs are listed in Procedure No. 112 of the *Site-300 Safety and Operational Manual*.

LLNL Type O

Materials or devices which need not be handled, stored, or labeled as explosives, unless they are close to other explosives which could initiate them.

LLNL Type C

Electroexplosive devices, requiring a rapid discharge of high electrical energy for initiation, which contain no initiating explosives (LLNL Type E) and are not sensitive to radio-frequency (rf) energy or electrostatic discharges from the human body. Type-C EEDs are well-characterized as to their safety and require typical threshold energies of 0.25 J (2.5×10^6 ergs) for initiation. Detonators assigned to this category are of the exploding bridgewire (EBW) or slapper/flying-plate type.

LLNL Type D

Electroexplosive devices which require only small amounts of electrical energy for initiation. The energy need only be applied through the resistance heating of a bridgewire. These devices are called hot bridgewire-type LEIs. They must have well-characterized safety limits, have design features to make them not sensitive to electrostatic discharges from the human body, and have a minimum no-fire current of 1 A/1 W for five minutes. Typical threshold energies for initiation are 0.001 J (10^4 ergs).

LLNL Type E

All initiating explosives, materials extremely sensitive to static sparks, and any device not meeting the criteria for Type O, C, or D.

Categorization

Categorization of explosive components and devices requires that all available safety data, design drawings, and other information regarding safe handling and use must be submitted to the LEI Committee for review and approval. This information shall be compiled on an Electroexplosive Component Data Sheet (see Appendix A). Testing and evaluation may be required when the manufacturer's data is incomplete, or when new lots of LEIs are to be recertified. Assignment of the LEI Type shall be based upon the above definitions and the available data, and an approved list will be generated for each Type.

Hazards of LEIs

LEIs often present the risk of injury or property damage exceeding that of EBWs and slapper-initiated devices. Among the reasons causing this are the wide range of sensitive explosive materials which can be used, and also because manufacturers use varying quality-control methods, causing differing levels of safety. Many specific energy inputs must be controlled in and around LEI operations.

Thermal

Many LEIs are designed to contain initiating explosives or pyrotechnic materials. By their very nature, these materials are sensitive to heat and open flame. If the explosive is subjected to any temperature above that usually found in normal testing environments (about 130 °F), it should be examined for possible thermal reactions. In the setup of experiments, LEIs must be kept away from heat sources and potential areas of accidental fires. Soldering on LEI electrical leads is generally prohibited, except with appropriate safety controls as outlined in an OSP.

Impact

Most known LEIs are not extremely sensitive to impact, such as an accidental drop from a normal work height. However, they must still be protected by careful handling and proper packaging. Hitting LEIs with tools, such as hammers, must not be permitted because of the sensitive explosive materials contained therein.

Lightning

Do not use or handle LEIs during electrical storms, or when lightning-detection equipment indicates the presence of potential atmospheric voltage gradients exceeding 3 kV/m (see *Site-300 Safety and Operational Manual*, Procedure No. 102).

Radio-Frequency Energy

Radio-frequency (rf) energy may be accidentally coupled to an LEI through the electrical leads used to fire the device. If sufficient rf energy is coupled to the bridgewire(s), resistive heating may cause an accidental firing. The sensitivity of LEIs to rf energy varies widely due to LEI bridgewire design, materials, and rf energy.

Each pertinent OSP must include a statement outlining the measures for preventing or controlling sources of rf energy. If there is any question about sources of rf energy, an rf-energy survey shall be done prior to handling of the LEIs. Use Table 1 to determine safe distances between rf sources and LEI operations. Leads must be shorted, both pin-to-pin and pin-to-case, until installed in the device.

Induced Electrical Power

Induced electrical power in the firing cables can cause accidental firings. Such currents and voltages are best prevented by isolating the LEI electrical leads and cables from *all* other electrical conductors, especially those carrying electrical power to equipment and those carrying high voltages and high currents.

Examine all operations for stray currents and voltages between metal parts, the firing cables, and ground. Appendix B discusses specific voltage and current limits.

Do not use electronic photoflash units near LEI operations because of the possibility of induced electrical power. Also, electrical energy arising because of galvanic action from dissimilar metals should be considered in the design of equipment setup.

Static Electricity

Static electricity presents a very serious hazard in operations involving LEIs. Static electricity can build up on nonconduction materials, and if this charge is not dissipated in a controlled manner through a resistance path, it will accumulate to a dangerous level and finally discharge in an uncontrolled manner. If static-sensitive explosive

materials are present, this discharge may cause an accidental firing of the device. Preventive measures must be designed into the operation to reduce the buildup and storage of such static charges. Proper selection of materials and bonding is the preferred method of control.

- Static charges can collect on personnel and their clothing. Fabrics such as rayon, wool, silk, nylon, and most synthetic materials readily become a source of static charges. Personnel handling static-sensitive explosive devices should not wear clothing made of such materials.

- Other sources of static electricity are plastic sheeting and bags, pressurized spray cans, and tapes. These materials generate significant voltages and must be controlled in and near LEI operations. Because of the potential risks of static electricity, LEIs shall be maintained at ground potential by shunting (pin-to-pin and pin-to-case) during handling.

Adhesives and Other Reactive Materials

Chemical compatibility must be designed into LEI operations and experiments to prevent accidental initiation. In cases where explosive materials in LEIs are exposed, examine each adhesive (or other potentially reactive material which may contact the explosive) for chemical compatibility prior to assembly. Exercise caution when using exothermic materials near LEIs.

Installation

Many LEIs are designed to be installed in an assembly and tightened to some pre-selected torque value which must not exceed the manufacturer's recommendation. In some specific applications, an LEI may be installed in an assembly providing adequate shielding of personnel from fragments and blast. The total assembly may then be reclassified as a Type O device. When this assembly is dismantled and the LEI is exposed, it shall revert to its original explosives classification.

Modification

LEIs received from the manufacturer or supplier shall not be modified except by knowledgeable people working under the direct control of an OSP which outlines the detailed steps involved. This type of OSP shall be approved by the LEI Committee in addition to the normal reviewers.

LEI Committee

Membership and Purpose

The LEI Committee is an interdisciplinary team of responsible scientists and engineers whose function is to review safety controls, handling, and characterization procedures for LEIs. *Overall safety responsibility remains, as always, with line supervision.* The purpose of the LEI Committee is to maintain a continuing review of the operational handling and control of LEIs to help ensure their safe use.

Functions and Responsibilities

The LEI Committee

- reviews the handling safety and the attendant hazards as well as the categorization of LEIs, following the recommendations set forth in UCAR-10074 (M. Finger, R. Guarienti, *LEIs, A Review: Recommendations and Implementation Plan for LLNL Management*, July 1981) and approved by Associate Directors R. D. Woodruff, W. B. Shuler, G. D. Dorrough, and H. C. McDonald;
- reviews, categorizes, and makes recommendations on the use of LEIs at LLNL;
- reviews and recommends appropriate handling procedures for each LEI category;
- reviews and recommends sensitivity testing procedures for LEIs;
- provides the Hazards Control Department with lists of approved LEIs; and
- recommends procedures and training for handling LEIs.

Procedural Requirements

The OSP controlling use of LLNL Type-D LEIs must outline the hazards associated with the units and what specific actions must be taken to prevent accidental firings and injuries.

The OSP controlling use of LLNL Type-E LEIs must also be reviewed by *both* the LEI Committee and the Hazards Control Department. The Procedure must cover all the safety controls for LLNL Type-D LEIs *plus* the additional hazards associated with the Type-E unit.

Purchasing LEIs

Use existing procurement channels to purchase LEIs. However, anyone purchasing an LEI shall request from the manufacturer the following information and also specify the indicated requirements:

1. details of construction (drawings), including the identity and quantity of explosives/pyrotechnics contained in the device;
2. all electrical characteristics including no-fire and all-fire currents, and electrostatic sensitivity (pin-to-pin and pin-to-case). The manufacturer must also state that the LEI meets the minimum requirement of 0.25 A for five minute no-fire. (Ideally, it should meet the 1 A/1 W five minute no-fire criteria) .

NOTE: The above information shall be collected by the requestor and transmitted to the LEI Committee for review well in advance of the intended date of use. As a general rule, no carbon-bridge systems and no conductive-mix initiation systems (where the conductive mix is used in place of a bridgewire) are permitted.

LEI Testing

If the safety-related information is not available from the manufacturer or supplier, the new LEI must be tested and evaluated. Also, if there is any question concerning the accuracy of the manufacturer's data, LLNL should test the LEI to remove any doubts. It is also advisable to verify the electrical characteristics of LEIs arriving at LLNL.

Testing of LEIs shall consist of at least an electrostatic-sensitivity test and a no-fire current test. In the electrostatic sensitivity test, there shall be no reaction or dudding of the component when subjected to 20 kV from a 600 pF capacitor through a 500 Ω resistor (DOD items are tested at

25 kV, 500 pF and 5000 Ω). This test shall be done to the LEI in both pin-to-pin (pins-to-pins) and pin-to-case discharge modes. A no-fire rating of 1 A/1 W for five minutes is required for Type-D LEIs and a minimum of 0.25 A for five minutes at the no-fire level for Type-E devices.

A facility designed for doing the electrostatic sensitivity and no-fire-current testing shall be equipped and maintained in an operable condition. Building 805, at Site 300, currently has the equipment to do these electrical tests.

LEI Work-Area Controls

The criteria for explosives operations are contained in the *Health and Safety Manual, Site-300 Safety and Operational Manual*, and the *DOE Explosives Safety Manual*. The general criteria for explosives laboratory operations (when less than 500 g of explosives are involved) are contained in the *Health and Safety Manual, Section 24.20*.

When LEIs are involved, the work area shall include controls to eliminate extraneous sources of electrical energy including rf and static. Restrict the use of portable radio transmitters to a safe distance. Grounding and electrical-bonding techniques are necessary for handling, but limit their use to approved LEI Handlers. Appendix B details general handling and firing requirements.

Labels

Each test unit, shot, or package containing an LEI shall be identified with a label to alert the Explosives Handlers. This label (LL-5406) will remain on the item from receiving through firing or disposal, and shall be used in addition to the Explosives ID Label (LL 4-299). Figure 1 shows label LL-5406 (the colors are orange and black).

Appendix A

Electroexplosive Component Data Sheet

1. Number or name used to identify this specific item: Requestor:
Date:
Quantity:

2. *Name of supplier or manufacturer: Category:
*Part No. /Lot No. Drawing No.

3. Hazard Classification:
Manufacturer's Recommended Hazard Class:
Manufacturer's Recommended Compatibility Group:
Dept. of Transportation Shipping Class:
Dept. of Transportation Shipping Name:
Specific DOT Approved Shipping Container:

4. Explosive, Pyrotechnic, or Propellant Composition, and makeup of part:

a. Explosive	Wt./Unit	Function	Location in Device
b. Total weight of explosive in component:			
c. Does any explosive contain metal additives? If yes, explain:			

5. Recommended Shelf Life:

Thermal Limits:	Upper	°F	°C
	Lower	°F	°C

 Other factors affecting shelf life or functioning:

6. Electrical Characteristics

*a. Max. No Fire(current)	A	W	time
b. Min. All Fire (current)	A	W	time
c. Max. Test (current)	mA		time
d. Mean Firing (current)	A		
e. Recommended Firing (current)		A	
*f. Bridgewire Resistance	$\Omega \pm$	Ω	
g. Bridgewire Material			

* Minimum data required for categorization.

7. Electrostatic Discharge Rating: DOE ; DOD

8. RF Sensitivity Data:

Frequency	Power to Fire (Watts)	Modes (pin to pin) or (pin to case)
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9. Chart: Function time vs current

10. The following documents should be attached to this data sheet:

- Detail drawing of component showing dimensions, explosive constituents, electrical schematic.
- Descriptive drawing of any DOT specially approved shipping container.
- DOT correspondence assigning approved DOT class and shipping name.

11. **General.** Note any special features of this device (thin film bridge, arc-resistant construction, high-resistance paths, only secondary explosives, bridgewire pin-to-case grounds, toxic materials).

* Minimum data required for categorization.

Appendix B

Handling and Firing of LEIs

General

This procedure is applicable to handling and firing Low-Energy Initiators (LEIs) at LLNL facilities and in field operations. An LEI is an electroexplosive device containing energetic materials designed and/or manufactured to be initiated by energies of 0.1 J or less. This is less energy than required for an exploding bridgewire (EBW) or slapper device. Any operation with LEIs must be covered by an approved Operational Safety Procedure (OSP) and any apparatus containing an LEI must be appropriately tagged and labelled. The *Health and Safety Manual*, Section 2.06, outlines the requirements of the OSP. The person handling the LEI must be trained and qualified specifically in this area (see *Health and Safety Manual*, Section 24.03).

Storage

Magazine and other approved storage is required for all explosives and small explosive devices. The magazine, cubicle, safe file, etc., must be located and placarded as outlined in the LLNL standards or controlling Safety Procedures. LEIs shall be stored as outlined in the *Health and Safety Manual*, Section 24.06.

Preparation

1. The LEI Handler is responsible for the safety of all operations with the LEI. The Handler must stop the operation if he is doubtful of its safety. Notify the Hazards Control Safety Team Leader of the situation.
2. Clear the immediate area of potential hazard of *all* personnel whose presence is not required for the completion of the operation.
3. Verify that LLNL standard safety signs are posted at all entrances to the work area to warn those who may enter.
4. Complete all adjustments to auxiliary and experimental equipment.
5. Verify that all sources of significant rf energy have been located and turned off. (See Table 1 in this Supplement for safe distances between rf sources and LEI operations).
6. Turn off, or otherwise render safe, all unnecessary sources of electrical energy in the immediate work area.
7. Before additional handling, verify that the LEI is the exact item authorized by the OSP for the job. *NOTE:* unless the LEI is positively identified, do *not* continue with the operation.
8. Have available a Type-I electrical meter authorized by the Explosive Systems Instruments Control Committee. See the *Health and Safety Manual Supplement 24.15* for details. Measure and record the LEI resistance.
9. Short together the electrical leads on the LEI pin-to-pin and pin-to-case at all times except when required for testing and installation.
10. All LEI Handlers and all other persons within the area of potential injury shall wear LLNL-approved eye protection. Handlers shall wear approved non-static-generating clothing.
11. The work area shall be free of excessive combustibles and sources of ignition.
12. The Handler may hand-carry the LEI from storage to the specific work area in a metal container, such as a metal ammo box, properly labeled and tagged to identify its contents.

Installation

1. Complete all the preparation steps listed above.
2. Check for stray voltage and current between the ground and the equipment (using a Type-I meter capable of reading voltage and current). *NOTE:* the voltages and currents must be 50 mV or less and 1 mA or less, both ac and dc. Do not continue the operation until stray electrical energies are below the values noted here.
3. The LEI Handler shall retain absolute control of the “safety key” (defined as any device which acts as a positive control of the energy source).
4. With the safety key in the Handler’s possession, remove the LEI from storage or from its container. *CAUTION:* From Step 3 through the last physical contact with the LEI, use electrical bonding techniques. Electrical bonding provides a conductive path between the Handler, the LEI, and the fixture or equipment involved to prevent development of an electrical potential between them.
5. Identify the LEI and inspect it for mechanical damage. *NOTE:* Send damaged LEIs to Site 300 for proper disposal. Return unknown or unidentified LEIs to storage to await proper identification, return them to sender, or send them to disposal.
6. Verify that the firing-set end of firing cable is shorted. Check the firing cable for stray voltages and currents. *NOTE:* Make all measurements with a Type-I det ohmmeter. Voltage and current on the firing cable must be zero, both ac and dc.
7. Position the LEI in the fixture or equipment as required by the operation.
8. Connect the shorted firing cable to the LEI. If applicable, open the short between the leads of the LEI after this connection has been made.
9. Close the bunker door or firing-tank door, or use whatever mechanism which provides protection from the blast or fragments.
10. Position safety warning signs as required.
11. Notify building or area personnel of the intended firing as required by existing procedures.
12. Check the LEI and firing cable assembly for electrical continuity, using a Type-I meter.
13. Connect the firing cable to the firing unit and fire the shot as outlined below.

Firing

1. Insert the safety key in the firing unit. Turn on the firing unit power supply and allow sufficient time for the unit to reach operating voltage.
2. Fire the LEI by triggering the firing unit. *NOTE:* If no sound is heard or if no other indication of firing is observed, wait about one minute and attempt to refire. If the shot still does not fire, there are two possible courses of action: (1) treat as a misfire and (2) put the firing operation in stand-by. If the problem can be resolved without personnel exposure, then correction may be made and the shot fired. If the problem cannot be resolved without personnel exposure, treat as a misfire. See *Misfire* section below.
3. Provide ventilation to remove detonation gases or allow time for dust to disperse.
4. Turn off firing-unit power supply and remove the safety key from the firing-unit control.
5. Remove the LEI firing cable from firing unit and short the control-room end of the cable.
6. The LEI Handler (with the safety key in his possession) shall check the area of the LEI to verify that the shot went and consumed all of the explosives. *NOTE:* If examination reveals an unfired LEI or remaining explosives, treat as a misfire.

Misfire

If no audible detonation is heard after triggering the firing circuit, the firing circuitry and the LEI(s) may be checked for continuity from *within* the protected location. If the firing circuits and LEI(s) appear operative, one or more attempts to fire may be made. If the LEI does not fire, take the following precautions:

1. Notify the Hazards Control Safety Team Leader of the misfire.
2. Disconnect and de-energize all shot electrical power sources.
3. Ensure that all personnel in the danger zone are aware a misfire has occurred and that they are to remain under cover until notified otherwise.
4. *Waiting Period.* Before any personnel are permitted to leave the cover of the protection location, observe a pre-established waiting period. In most situations, establish this waiting period as thirty minutes, minimum.
5. Initiate a carefully thought-out review of the situation in consultation with another knowledgeable person.
6. After an agreement has been reached, one qualified person should cautiously approach and examine the setup to verify that it is safe before other personnel are permitted to leave the cover of the protected location.
7. With minimum personnel present, remove the unfired LEI and short the electrical leads if possible.
8. Package the LEI, label it as misfired, and remove it to storage.
9. Arrange for disposal of the LEI. The following information must be sent with the LEI for disposal:
 - a. a designation describing the specific device;
 - b. the data sheet (or equal) which describes the hazardous properties;
 - c. a brief description of any electrical, thermal, or dynamic testing to which the unit has been exposed.